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Air Warrior Baseline Evaluation, Volume I, Summary

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Rotary-Wing Aviation Research Unit

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14. ABSTRACT *(Maximum 200 words)*:

Air Warrior is a U.S. Army program that has been initiated to improve the fighting capabilities of helicopter crews in contaminated combat environments. The Air Warrior baseline simulations were conducted to identify and quantify the effects on aircreww mission and task performance of wearing the current MOPP IV protective and survival ensemble. Differences in performance and workload between the MOPP IV ensemble and normal flying gear were obtained for AH-64 crews flying night missions and performing a set of daylight maneuvers and tasks. The MOPP IV ensemble was found to cause major increases in workload and reduce performance on numerous aircreww tasks. Specific effects of the MOPP IV ensemble on aircreww discomfort, pain, and task performance were obtained through detailed debriefings.

15. SUBJECT TERMS

Air warrior	Protective ensemble	Chemical-biological	Simulation
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Education and Training Technology

FOREWORD

As it initiated the Air Warrior development program, the U.S. Army Aviation and Troop Command surveyed the potential helicopter flight simulators that could provide the support required by the program. It concluded the best simulator facility for much of its requirements was the Simulator Training Research Advanced Testbed for Aviation (STRATA) at the Fort Rucker, AL Rotary-Wing Aviation Research Unit (RWARU) of the U.S. Army Research Institute for the Behavioral and Social Sciences. It provided high-fidelity simulation of the AH-64 gunship that used actual crew stations and had desirable flexibility in combat mission scenarios and research capabilities. The STRATA was rapidly modified to provide a number of Air Warrior missions and the required data collection and analysis capabilities.

After tasking in June 1995, preliminary single-pilot baseline simulations of protective ensemble effects on flying maneuvers were conducted during July, and an interim briefing was conducted for Air Warrior Program personnel. Full-crew mission simulations were developed and conducted during August, September, and October to check and refine the missions and associated data collection and analysis. The Aviation Technical Test Activity and the Aviation Training Brigade at Fort Rucker provided AH-64 qualified pilots for these initial simulations. Expertise on proper wear and fitting of the MOPP IV ensemble and survival equipment was provided by the Test Activity. The test plan for conducting the baseline Air Warrior simulation evaluations was approved by the Air Warrior Program Office in November 1995. The main data collection began in late November and was completed in February 1996.

Interim results of the Air Warrior baseline simulation evaluation, based on debriefing comments, were provided to the Program Office in March 1996.

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The Aviation Technical Test Activity (ATTC) at Fort Rucker provided the MOPP IV and survival ensembles that were tested, and SFC Michael C. Kingery of ATTC the expertise on how to wear and fit them properly. ATTC and the Aviation Training Brigade at Fort Rucker provided the pilots for all of the preliminary simulation testing and some of the main baseline mission flying. The comprehensive debriefing form that was used was a slight modification of a form used by the ATTC that was developed by Steven Hale of the Essex Corporation. A comprehensive set of anthropometric measurements on the participating pilots was provided by Ann Carson of GEO-Centers, Inc., under contract to the U.S. Army Aeromedical Research Laboratory.

We owe a special debt of gratitude to the pilots who participated in these Air Warrior baseline simulations. Recognizing the importance of the Air Warrior program to the future combat effectiveness, survival, and safety of Army aviators, they participated with dedication in a week-long series of missions that required them to endure substantial discomfort and pain.

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Introduction

Air Warrior (helicopter crews), Land Warrior (ground soldiers) and Mounted Warrior (combat vehicle crews) are the three U.S. Army programs that have been initiated to improve the fighting capabilities of U.S. soldiers in combat environments contaminated by NBC (nuclear, biological, chemical) agents. Air Warrior is the rotary wing aviation focus for providing a mission-tailorable system that standardizes and integrates aviation life support equipment for Army, Navy and Marine Corps aircrew personnel during helicopter flight and ground operations. Air Warrior will consist primarily of aircrew mounted mission and survival equipment and protective clothing and equipment, and provide integrated interfaces with aircraft mounted equipment. Lack of effective design and integration of current equipment for aircrew requirements has resulted in helicopter crew members being furnished with a large volume of personal gear that becomes a physical burden, encumbers performance, and causes rapid build-up of heat stress, discomfort and pain.

The Air Warrior system will provide state-of-the-art integrated chemical and biological agent protection, noise protection, heat stress reduction, crash and post-crash survivability, concealment and environmental protection, ballistic protection, night vision capability, heads-up displays, nuclear flash protection, directed energy eye protection, and flame/heat protection. The Air Warrior design will improve overall aircrew mission performance, aircrew comfort, aircrew and crew station interface, safety, and survivability. It will also provide for the integration of aircrew's personal protective gear with other essential functions, such as visual enhancement, physiological comfort and hygiene, escape, evasion, and survival. The stress of wearing excessive nonintegrated equipment will be minimized.

The Air Warrior program is being conducted by the Aviation and Troop Command Program Manager for AirCrew Integration Systems. The development program includes plans for statistically rigorous analysis of performance and protection to define system requirements and the improvement provided by the Air Warrior system ensemble and its components. These plans include the use of simulation to evaluate the effects of baseline (the current MOPP IV versus unencumbered) ensembles, and Air Warrior conceptual and prototype ensembles. The Army Research Institute STRATA (Simulator Training Research Advanced Testbed for Aviation) high fidelity AH-64 gunship simulator, that uses actual crew stations, was selected as a primary simulation resource for Air Warrior evaluations.

STRATA was used in an iterative series of missions to develop and refine a set of appropriate missions, measures and analyses for evaluation of Air Warrior baseline and future ensembles and components. All the baseline simulations in STRATA involved comparisons of flying in the full overwater MOPP IV protective and survival ensemble (NBC) with flying in standard (STD) unencumbered flying gear. The initial "Quick Look" simulation used only pilots in the AH-64 rear crew station flying a non-combat mission of typical flight maneuvers, and range-type firing on fixed targets. The Quick Look was followed by a series of full crew combat mission simulations during which the missions, measures, and analyses were refined into their final form used for the baseline Air Warrior simulations being reported here. This summary is the first of three volumes providing the results of the Air Warrior baseline ensemble evaluation in STRATA. Volume two provides expanded results, and volume three provides all data used during the analysis and interpretation of results.

Objectives

Objectives of the Air Warrior baseline simulations were to identify and quantify the effects of wearing the current aircrew MOPP IV nuclear-biological-chemical and survival ensemble (NBC).

The simulations were designed to generate baseline data on the effects of the NBC on mission performance, flying performance, specific tasks, and on pilot discomfort and pain.

Method

Seven AH-64 crews flew four combination daylight and night combat mission scenarios in NBC, and the same four scenarios in standard flying gear (STD). The mission simulations were conducted at Fort Rucker in the Army Research Institute high fidelity AH-64 STRATA. The order of flying in NBC or STD gear was counterbalanced, and threat element dispositions were varied between the first and second repetitions of each scenario. Table 1 indicates the daylight maneuvers and tasks, and night mission segments, that were selected for analysis.

Table 1. Daylight and Night Mission Analyzed Maneuvers, Segments and Tasks

Daylight Maneuvers and Tasks	Night Mission Segments and Tasks
Before Night Mission	Program Doppler Nav System
Controls Sweep	Program Fire Control Computer
Slope Landing	Forward Assembly Area Takeoff
Hover	Dogleg
Hover Taxi	120 kt at 100 ft
Hover Pedal Turn	Approach Holding Area
Evasive Quick Turn	Set Freqs 3 Radios
Pilot Fire 30mm	Formation Takeoff
Copilot-Gunner Fire 30mm	Formation Fly
	Takeoff at Holding Area
After Night Mission	Fly to Battle Position
Slope Landing	Unexpected Engagement
Hover	Recon at Phase Line
Hover Taxi	Engage at Battle Position
Hover Pedal Turn	Set Freqs 3 Radios
Evasive Quick Turn	Fire Rockets
180 Autorotation	Initial Egress
Controls Sweep	Forward Assembly Area Approach
	Forward Assembly Area Rollout

The daylight maneuvers flown both before and after each night mission consisted of a slope landing, hover, hover taxi, hovering pedal turn, and evasive quick turn. The latter non-standard maneuver involved maximum forward acceleration, a tight 180-degree turn, and maximum deceleration (to reflect rapidly flying behind masking when fired on from the rear, and then turning to engage). Before the night mission, the pilot and copilot-gunner (CPG) each fired the 30 mm gun at two fixed targets, and a 180-degree autorotation was flown after each night mission. In addition, there was a sweep of all four flight controls over their full range before and after the night mission. Total night plus both daylight mission durations varied between 1 to 2 hours, and the AH-64 crew stations were well cooled to preclude serious overheating in the NBC. Prior to the first data mission, each crew flew two training sessions (the first in STD gear, the second in NBC). Both sessions included the before-after maneuvers and tasks, and a night training mission different from the data missions.

After each mission, both pilots estimated the level of six different aspects of workload as defined by the Task Load Index (TLX) during the ingress, combat, egress, and maximum workload phases of the mission. After most and before some missions, one of the pilots took a set of PC selection-type tests on cognitive, multiaxis tracking and attention abilities. After each mission in NBC, a detailed debriefing of both pilots was conducted using a form that included all the suspected NBC effects.

Data were recorded during the simulated flights for 50 different parameters reflecting the state of the vehicle and its flight controls and switches, pilot helmet angles, threats line of sight, and the accuracy and effect of each weapon round fired. Subsets of these parameters relevant to specific night mission and daylight tasks were selected for data analysis. Weapon firing at any time during the night mission, and during the daylight firing tasks, was analyzed for accuracy and effect. Twenty-four night mission tasks, and 15 daylight tasks, were selected for analysis. A standard subset of five basic statistics for 19 vehicle, controls and helmet angle states, was used for most of these tasks. The data analyses resulted in evaluation of more than three thousand potential measures for their ability to discriminate the effects of NBC on performance. The results will be provided in two primary reports; one for the operational user, the other with detailed results for the technical user.

Findings

Workload

Pilot subjective opinions in workload estimates and their debriefing comments indicate that the NBC increased their workload substantially. Workload estimates for NBC were higher consistently for all six TLX aspects of workload in all four mission phases. These differences for each of the four mission phases were all highly significant ($p < .005$ [probability less than .005]) for all aspects of workload except "performance." Table 2 summarizes the results, showing the average workload over the four mission phases surveyed, for the six different aspects of workload. The effort aspect was found to have the highest workload rating in NBC. In STD, the performance aspect had the highest and the frustration and physical demand aspects the lowest ratings. The greatest difference between NBC and STD was for the frustration and physical aspects, and the

Table 2. Average Workload and Differences for NBC and STD

ASPECT OF WORKLOAD	NBC	STD	DIFFERENCE	NBC % INCREASE
MENTAL DEMAND	56.4	44.9	11.5	26
PHYSICAL DEMAND	58.4	39.2	19.2	49
TEMPORAL DEMAND	56.5	41.1	15.5	38
PERFORMANCE	59.4	53.8	5.6	10
EFFORT	62.5	45.0	17.5	39
FRUSTRATION	58.0	34.2	23.8	69
Average All Six Aspects	58.5	43.0	15.5	36
Average Less Performance	58.4	40.9	17.5	43

least difference for the performance aspect. For the frustration aspect there was a 69% rating increase in NBC and for the physical aspect a 49% increase, but only a 10% increase for the performance aspect. Average workload ratings for all six aspects were 36% higher for NBC than for STD. The ratings indicate the pilots had to shift from a primary focus of their workload on

mission performance in STD, to much higher (a 43% average increase) levels of workload on the other five aspects in NBC.

Pain and Physiological Stress

The NBC caused substantial pain for most crewmembers on most missions. The locus of the most common source of pain, "hot spots," was evident from points, lines and areas of red welts on the scalp that usually lasted well beyond an hour after the mission. On the longer missions for some crews, the level of pain built up to levels which they indicated they could have tolerated for only a few more minutes. Expert assistance was provided to assure the mask and hood were donned to best minimize hotspots, yet there were many requests for breaks during the "before" daylight maneuvers, or just before the night mission, to try to adjust out hot spots. Other sources of pain were from pressures of the NBC on the chest, abrasions of the face from the mask when turning the head, life raft pressures on the back, and locking of the torso in a rigid position in the CPG station between the optical relay tube mount and the seat back.

The primary physiological stress was heat stress, which built up to barely tolerable levels for many of the pilots on the longer missions. High levels of heat stress occurred even though the crew stations were kept very cool. Most of the crews were completely soaked from sweat after a mission. Sweat running down into pilot's eyes and pooling in their buttocks, gloves and boots, diverted their attention and created difficulties in accomplishing some mission tasks. Many of the pilots indicated they were incapable of immediately flying another mission, due to their extreme levels of physiological and mental distress and pain at the end of these "cool" missions in NBC. Pilots expressed concern that actual combat often would require an immediate second or third mission under much hotter conditions, which would be impossible in current NBC without almost certain catastrophic consequences.

Task Times and Errors

NBC increased the mean time to set radio frequencies (see Table 3) in the holding area by 185% (123 versus 43 seconds), and median time by 126% (81 versus 36 seconds). A few extra long setting times increased the mean times substantially over median times. The statistics used for data analysis were selected to reflect the "typical" median times, and means comparisons avoided that might reflect just a few extra large values. The median time to program the doppler navigation system increased in NBC by 51%, but only by 5% for programming the fire control computer. The NBC increased pre-takeoff checks mean time by 21% and median time by 7.5%, but these differences were not at all significant due to large inter-trial variability. The crews reported numerous switching errors which would have increased task times, and could have--but usually did not have--serious consequences. Many switches throughout both crew stations could not be identified visually. The crews developed logical "feel" processes for locating certain switches, in spite of the poor tactile sensitivity through their flight and NBC gloves. In one instance a pilot shut off his only engine due to a switching error. There were numerous instances of the Helicopter Emergency Egress Device (HEED) bottle/case inadvertently actuating the manual stabilator switch, with one pilot reporting dozens of such episodes. Each such error has the potential of causing an accident, and requires attention to reset the master caution light. The consistently reported requirement to move or reach around the NBC mask hose would increase task times. It is evident the increase in task times and errors with NBC varies widely with specific design aspects of the crew station elements involved in a task.

Perceptual, Procedural, and Mental Abilities

Crews reported a large number of ways in which the NBC degraded their visual and psychomotor abilities. The continual extra attention required to compensate for these degraded

Table 3. Time (sec) to Perform Procedures in STD and NBC

	MEAN		% DIFF	MEDIAN		% DIFF
	STD	NBC		STD	NBC	
SET RADIO FREQUENCIES IN HOLDING AREA						
1ST	23.4	68.3	192	18.2	37.7	107**
2ND	12.4	30.0	141	8.3	24.5	194**
3RD	7.2	24.6	241	7.0	14.5	107**
ALL	43.1	122.8	185	36.0	81.2	125**
AFTER COMBAT (Damage; One Engine; Many Pre-sets in NBC)						
1ST	44.4	46.9	6	28.3	31.7	12
2ND	32.1	67.5	110	27.2	32.3	19
3RD	30.1	45.5	51	9.0	18.0	100**
ALL	106.6	159.9	50	72.5	124.0	71**
PROGRAM DOPPLER NAVIGATION SYSTEM	152.7	211.5	39	128.5	194.3	51**
PROGRAM FIRE CONTROL COMPUTER	89.8	97.9	9	67.5	71.0	5
PRE-TAKEOFF CHECKS	57.3	69.5	21	44.5	47.8	7

** Significant at $p <$ (less than) 0.01

abilities, in combination with frequent extra attention devoted to trying to deal with pain and physiological stress effects, was reported to detract from the attention that should have been devoted to the mental decision aspects of mission safety, survival and performance. The effects of the required extra attention appeared to accumulate during the mission. Pilots often reported that in NBC near the end of the longer missions, they had reached a point of mental disorganization, and had adopted "don't care--just get it over with" attitudes that resulted in numerous safety of flight violations. Flying the mission in NBC rather than STD did not result in substantial differences in performance on the PC-based tests after the mission.

Vision through the mask lenses was attenuated, peripheral vision was limited, vision near the edges of the mask lenses distorted, and the right mask lens became badly scratched by the Integrated Helmet And Display Sight System (IHADSS) lens ring. The NBC highly constrained torso and neck flexibility. This forced pilots to try to scan and see primarily by eye deflections with little normal head and torso motion. This, in turn, forced them to try to see through the edges of the mask lenses where vision was poorest. Supplementary lighting usually was required to see radio frequency numbers due to lens attenuation, even though cockpit lighting usually was set to maximum brightness. Trying to see and set radio frequencies forced an extreme combination of torso twisting and head turning, finding and using supplementary lighting to see the numbers through the lens attenuation, holding the hose out of the line of sight, and trying to set in the frequencies with the extremely poor tactile feel through the glove fingertips. Vision of the rear parts of the side consoles was impossible. Potentially critical switches are located on the rear side consoles, and errors with them could have serious consequences.

Table 4 provides objective data indicating that for several mission segments and daylight maneuvers, NBC substantially reduced the range of pilot helmet rotation in azimuth, and resulted in a lower mean angle of helmet elevation on maneuvers involving high turn rates. The much larger range in pilot helmet elevation angle, while flying to the battle position, was due to much lower minimum helmet angles. The lower helmet angles with NBC probably reflect greater use of instrument panel versus external visual cues.

Table 4. NBC Effect on Rotation of Pilot's Helmet During Night Mission Segments and Daylight Maneuvers Before and After Night Mission (Minus Values Are Rotation to the Left)

MEASURE Mission Segment/Maneuver Statistic	STD (Deg)	NBC (Deg)	RATIO IN % (NBC / STD)
PILOT HELMET AZIMUTH			
Engage at BP (During Night Mission)			
Minimum	-47.8	-18.7	39 **
Range	96.2	59.0	61 *
120 kt at 100 ft (During Night Mission)			
Minimum	-15.1	-8.2	54 **
Range	44.3	25.4	57 **
Initial Egress (During Night Mission)			
Minimum	-27.1	-13.4	49 **
Range	52.1	36.5	70 **
FAA Approach (During Night Mission)			
Minimum	-23.2	-2.3	10 **
Range	55.8	13.0	23 **
Evasive Quick Turn (Before Night Mission)			
Range	42.4	30.9	73 **
Evasive Quick Turn (After Night Mission)			
Range	43.5	32.7	75 **
PILOT HELMET ELEVATION			
Fly to Battle Position (During Night Mission)			
Minimum	-11.7	-27.3	233 *
Range	12.5	26.9	215 **
Evasive Quick Turn (Before Night Mission)			
Mean	-2.3	-4.7	205 **
Evasive Quick Turn (After Night Mission)			
Mean	-1.9	-4.6	238 *
180 Autorotation (After Night Mission)			
Mean	-2.0	-5.5	274 **

* Difference significant at $p < 0.05$; ** Difference significant at $p < 0.01$

Mission Effectiveness and Survival

There were few substantial negative effects of NBC on mission effectiveness and survival that were indicated from analyses of objective data. However, in debriefing comments, the pilots

were unanimous that there would have been major deterioration in task and mission performance, safety and survival if they had been required to immediately fly another mission, as often would be required in actual combat. Table 5 summarizes the results for NBC effects on night mission effectiveness and survival, and daylight 30 mm gun firing on stationary targets.

Table 5. NBC Effects on Night Combat Engagements and Daylight Gun Firing

	STD	NBC
NIGHT MISSIONS (Summary Over All Missions)		
Kills (Total)	122	128
Missile Kills	89	83
Gun Kills	33	45
Missiles Fired	123	119
Gun Rounds Fired	3616	4060 **
Gun Hits	742	891 **
Gun Rounds Miss Distance (Meters)		
In the Ground Plane	376	438
In Vertical Plane at Target	32	43
THREAT ATTACKS ON OWNSHIP		
Number	13	16
Kills	9	11
Hits	38	46
FRATRICIDE		
Episodes	9	11
Kill (UN Van)	0	1
Hits (2 on UN Van, 3 on M1A1)	0	5 *
DAYLIGHT GUN FIRING		
Rounds by Pilot to Kill Both Targets	85	70
Rounds by Gunner to Kill Both Targets	65	86 *
Error (Meters) in Ground Plane		
Pilot	383	444
Gunner	373	437 *
Error (Meters) in Vertical Plane at Target		
Pilot	19	21
Gunner	21	25

* Difference significant at $p < 0.05$; ** Difference significant at $p < 0.01$

For all night missions, there were 6 more kills in NBC (128) than for STD (122). During the night mission when in NBC, there were 7% fewer missile hits and kills, and 3.5% fewer missiles fired. However, there were 36% more (45 versus 33) night mission kills by the CPG with the 30 mm gun when flying in NBC. On the night missions when in NBC: there were 12% more gun rounds fired (4036 versus 3616) with 1.5% more hits per round, resulting in 20% more (891 versus 742) total gun hits. When in NBC, gun rounds average miss distance on the ground plane was 17% greater (438 versus 376 meters), and average miss distance in the vertical plane through the targets was 33% greater (43 versus 32 meters). Except for gun rounds fired and gun hits, these differences did not reach the statistical significance level of less than 0.05 chance probability.

When in NBC, there were 23% more threat attacks on ownship (16 versus 13), 22% more kills (11 versus 9), 21% more hits (46 versus 38), and 7% more rounds fired (73 versus 68). Due to the limited number of data points, none of these differences were statistically significant.

The number of fratricide episodes in NBC were 22% more (11 versus 9) than for STD. There was one kill (UN van, due to close proximity to missile exploding on BMP) and 5 gun hits (3 on M1A1 and 2 on UN van) on friendlies when in NBC, and none when in STD. There were a total of 219 gun rounds fired on or close to friendlies while in NBC, and 199 while in STD. Due to the limited number of data points, none of these differences were statistically significant.

In firing at fixed targets during daylight, the pilot required 18% fewer rounds to kill the targets when in NBC (70 versus 85), while the gunner required 33% more rounds (86 versus 65). The pilot's ground plane miss distance was 16% greater in NBC than when in STD (444 versus 383 meters), and the gunner's 17% greater (437 versus 373 meters). In NBC pilot miss distance in the vertical plane through the target was 8% more (21 versus 19 meters), and the gunner's 19% more (25 versus 21 meters). For the gunner these differences were less than or very close to the 0.05 level of significance.

<u>Flight Control and Safety</u>

The flight control measure results as a whole, reflect a reduction in the maneuver envelope when wearing NBC, and a reduction in precision of control after NBC has been worn for an hour or two. A large number of statistically significant results were obtained for the numerous objective measures relating to flight control which were examined. There were considerably more significant results than would be expected by chance. This summary covers only a few of the more significant results. More detailed results may be found in the main reports for the military (Vol. II) and technical and scientific (Vol. III) user. Table 6 summarizes some of the more significant findings on the effect of NBC on flight control. Table 7 shows the results found on limitations in range of motion of the flight controls.

<u>Crashes</u>. NBC had little effect on crashes. During the night mission, there were 9 crashes in NBC and 10 in STD. During the daylight maneuvers, before the night mission, there were no crashes in NBC and 3 in STD. During the daylight maneuvers (excluding autorotations), after the night mission, there were 7 crashes in NBC and 3 in STD. The chance probability associated with just the increase for NBC from zero before to 7 crashes after the night mission is .008. During the autorotations, after the night missions, there were 13 crashes in NBC and 16 in STD.

<u>Daylight Maneuvers and Tasks</u>. Before the night mission, NBC resulted (see Table 6) in lower heights for hover and hover turns, and greater maximum height, height variability, and height range for the evasive quick turn maneuver. Wearing NBC resulted in lower altitude above the ground and less variability in altitude when firing the 30 mm gun, especially when the CPG was firing. Diameter of the evasive quick turn was larger in NBC both before and after the night mission. Before the night mission in NBC in the evasive quick turn, more forward cyclic (acceleration) and less aft cyclic (deceleration) were used. Before the night mission, the hover position was located farther forward in NBC. After the night mission, there was more variability and range while wearing NBC for many of the vehicle states, positions, and flight control parameters during the hover, hover taxi and hover pedal turn maneuvers.

<u>Night Mission</u>. When firing at the battle position in NBC, altitude above ground was lower and the variability and range of altitudes less than when in STD (see Table 6). With NBC, the mean and maximum position for non-formation flight takeoffs from the holding area were significantly farther to the north than with STD. This appears to result from taking longer in NBC to decelerate to a stop during the prior landing at the holding area.

Table 6. Flight Control Effects of NBC

	DAYLIGHT MANEUVERS			
	Before Night Mission		After Night Mission	
MEASURE Maneuver Statistic	STD	NBC	STD	NBC
ALTITUDE ABOVE GROUND (Feet)				
Hover				
Mean	5.2	4.8 **		
Hover Turn				
Mean	5.5	4.9 *		
Pilot Fire Gun				
Mean	7.9	5.7 *		
Range	7.7	6.8 *		
Gunner Fire Gun				
Mean	8.1	6.5 **		
Range	4.5	2.8 *		
Evasive Quick Turn				
Range	80.9	91.4 **		
FORE-AFT POSITION ERROR (Meters; + Mean Is Forward of Spot)				
Hover				
Mean	3.1	7 **		
Hover				
Variability			0.8	1.1 **
LATERAL POSITION ERROR (Meters)				
Hover				
Variability			0.8	1.2 **
TURN DIAMETER (Meters)				
Evasive Quick Turn				
Range	42.8	69.5 **	54.7	64.2 *
LONGITUDINAL CYCLIC (% from Trim)				
Evasive Quick Turn				
Minimum (Acceleration)	23.4	26.2 **	22.8	27.4
Maximum (Deceleration)	27.9	17.4 **	25.9	17.9 *
	NIGHT MISSION			
ALTITUDE ABOVE GROUND (Feet)				
Engage at Battle Position				
Mean			67.3	53.3 **
Variability			29.5	15.2 **
Maximum			144.0	88.1 **

* Difference significant at $p < 0.05$; ** Difference significant at $p < 0.01$

Control Range of Motion. At the start and end of each mission, limit to limit sweeps of the four primary flight controls were conducted to determine any limitations in their range of motion due to the NBC ensemble. The NBC was found to limit the aft motion of the cyclic stick substantially, and to produce some limitation in cyclic motion to the left. Table 7 summarizes the effect of these limitations for two airspeed trim conditions, hover and 120 knots. The table shows the percent of the range of motion, from the trim position to the mechanical stop, that is available to decelerate or accelerate the helicopter. The columns of the table are based on anthropometric data from the control sweeps of the percentile values of limits of control range of motion. Crews with one or both pilots that had thick bodies or legs caused the most limitations in control motion that are found at the higher percentiles. In the first line of Table 7 of values for the hover trim condition, it can be seen that for STD flying gear no aft motion limitation occurs until the 75th percentile, and for the most limitation at the 100th percentile, 77% of the aft motion range is still available. In NBC, however, at the 2nd percentile sweep of least limitation in aft motion for any crew, only 74% of the motion range to the stop is available. For the sweep at the 100th percentile with the most limitation in aft motion, only 1% of the motion range is available! These major limitations on aft cyclic motion confirm observations of and debriefing comments by some crews, that lack of aft cyclic motion caused major flight control problems. To decelerate to a hover, these crews had to use pedal turns of the fuselage combined with lateral rather than aft cyclic control inputs. To hold a hover, these crews reported they had to "suck in their gut," and could not maintain it very long. For the 120 knot trim condition, in NBC for the most aft motion limitation at the 100th percentile, 41% of the full aft motion range is found to be available for deceleration.

The limitation in leftward cyclic motions was found to have more effect for 120 knot trim than for the hover trim condition. NBC reduced the available motion range for the more limited percentiles by 10 to 25% from the range obtained for STD flying gear.

Table 7. Percent of Available Aft and Left Motions of Cyclic Flight Control for Trim Conditions, Based on Motion Limit Percentiles from Controls Sweep Task

	Crew Anthropometry Motion Limitation Percentiles									
	Smallest 2	5	10	25	50	75	90	95	98	Largest 100
	Aft Motion Available from Cyclic Trim Position									
Hover Trim										
STD	100%	100%	100%	100%	100%	99%	97%	92%	90%	77%
NBC	74%	66%	62%	49%	40%	29%	20%	11%	6%	1%
120 Knot Trim										
STD	100%	100%	100%	100%	100%	100%	98%	95%	94%	87%
NBC	84%	80%	78%	69%	64%	58%	53%	47%	44%	41%
	Left Motion Available from Cyclic Trim Position									
Hover Trim										
STD	100%	100%	100%	100%	100%	98%	90%	81%	76%	68%
NBC	100%	100%	100%	97%	87%	77%	68%	66%	59%	57%
120 Knot Trim										
STD	100%	100%	100%	100%	100%	97%	88%	78%	72%	64%
NBC	100%	100%	100%	97%	85%	74%	63%	61%	53%	51%

Conclusions

The Air Warrior baseline simulations provide aircrew descriptions of a large variety of ways in which NBC degrades combat mission and task performance, and crew physiological and mental states. For a number of types of performance, statistical analyses of objective performance data confirm the pilot opinions. However, the results appear to reflect mainly the degradation due to the physical interference of NBC with performance. Pilot comments indicate and data near the end of the missions suggest, that major breakdowns in physiological and mental well-being that could be expected to have major mission performance consequences, were just beginning to occur near the end of these baseline mission simulations.

Major effects of NBC on objective measures of crew performance were found mainly for crew station procedures involving both vision of and fingertip manipulation of control panel items. NBC also was found to produce major limitations in the rotation of the helmet during high turn rate maneuvers. The precision of flight control in maneuvers at the end of the mission was found to be reduced in NBC. Aircrew workload estimates were much higher when flying in NBC, and indicated they had to shift from a primary focus on mission performance in STD flying gear, to much higher levels of attention and effort in dealing with the demands and frustrations of the NBC ensemble.

The STRATA Air Warrior baseline simulation results and experience provide a solid foundation for conducting future simulations to evaluate the performance effects of improved Air Warrior systems and components. The simulation methodology; missions, maneuvers and tasks; measures; and analyses, appear to be effective for evaluating the performance effects of Air Warrior development products. The results and experience from conducting these baseline simulations should allow future simulations to be conducted efficiently, and tailored to focus on specific issues when required.